Distortions of perceptual judgement in diagrammatic representations

David Peebles

Department of Behavioural Sciences, University of Huddersfield, UK
email: D.Peebles@hud.ac.uk

Introduction

Studies have demonstrated that the perception of graphical elements in a figure can be distorted by the relationships between them. Two well-known examples are shown in Figure 1. In the Müller-Lyer illusion (left), perceptual judgements of line length are distorted by the acuity of angles subtended by connecting lines. In the Parallel Lines illusion (right), the lengths of two parallel lines are perceived to be closer than they actually are (assimilation) or more different than they actually are (contrast), depending on the ratio of the line lengths and the distance between them.

Figure 1: Two visual illusions affecting the perception of line length: the Müller-Lyer illusion (left) and the Parallel Lines illusion (right).

Diagram designers must be aware of how low-level visual features of graphical representations can facilitate or hinder the interpretation of information. Previous research has shown that visual illusions can have a strong effect on perceptual judgements in commonly used diagrams (e.g., Poulton, 1985; Zacks, Levy, Tversky and Schiano, 1998).

Police Performance Monitors

In 2003, the UK government introduced the *Performance Monitor* (Police Standards Unit, 2003, 2004[a]), similar to the one in Figure 2. Performance monitors, a variation of a diagram otherwise known as the *radar* or *kiviat* chart, were designed to summarise performance data for individual police forces in five key *domains* (citizen focus, promoting public safety, resource usage, investigating crime, and reducing crime) and to allow easy comparison with average performance computed from a set of similar forces.

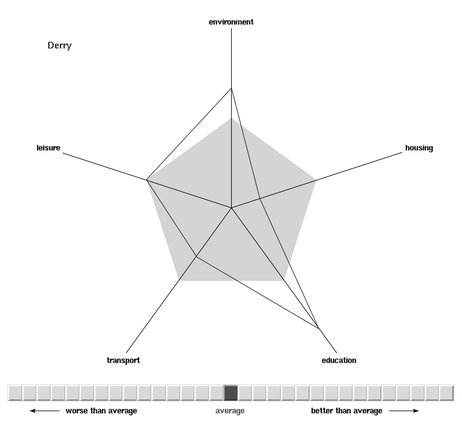

Figure 2: Kiviat chart used in the experiment.

The police performance reports also include bar charts (similar to the one in Figure 3) to illustrate the spread of performance for the most similar police forces in each domain. In the police performance bar charts, each bar represents the value on that domain of one of the forces from which the average has been computed.

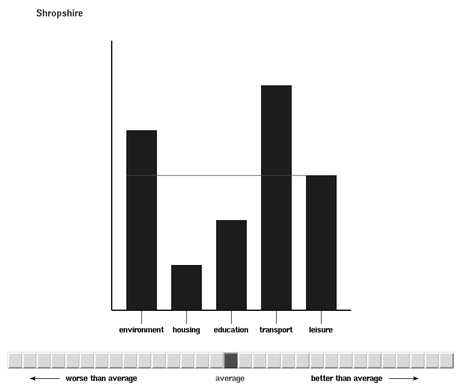

Figure 3: Bar chart used in the experiment.

One striking feature of both the kiviat and bar charts is the lack of any tick marks on the spokes or axes. The purpose of tick marks is to locate numerical values relative to coordinates in the chart or to provide an objective reference frame within which to compare lengths. Without such a reference frame, it may be the case that perceptual judgements of quantities such as line length become more susceptible to distortion by visual illusions such as the Müller-Lyer or Parallel Lines illusions.

[a] http://www.policereform.gov.uk/docs/performancemonitors.html

Experiment

The performance monitors and bar charts were designed to allow a rapid visual comparison of an individual institution's performance with a meaningful average. An experiment was carried out to determine whether the perceptual judgement of this distance for a particular target domain is affected by the values of the surrounding domains. In both the kiviat and bar charts, visual patterns formed by combinations of values are very similar to those found in the Müller-Lyer and Parallel Lines illusions, respectively. The hypothesis being tested is that, without anchor points such as tick marks, these patterns will affect viewers' perceptual judgements in a systematic way. A line graph (Figure 4) was also used in the experiment which, although very similar to the bar chart, would not be susceptible to the Parallel Lines illusion.

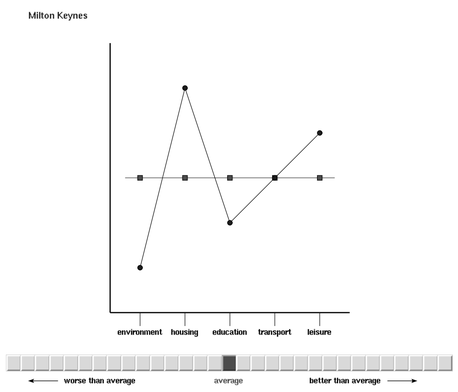

Figure 4: Line graph used in the experiment.

The spokes of the kiviat chart and the y axes of the bar chart and line graph were divided into six sections (invisible to the participants), the locations of which can be seen in Figures 2–4. The average value was located at the centre of the y axes and kiviat spokes.

Below each diagram was a scale consisting of 31 buttons. The 15 buttons on either side of the centre "average" button allowed the scale to be divided into six equally sized units, each containing four buttons.

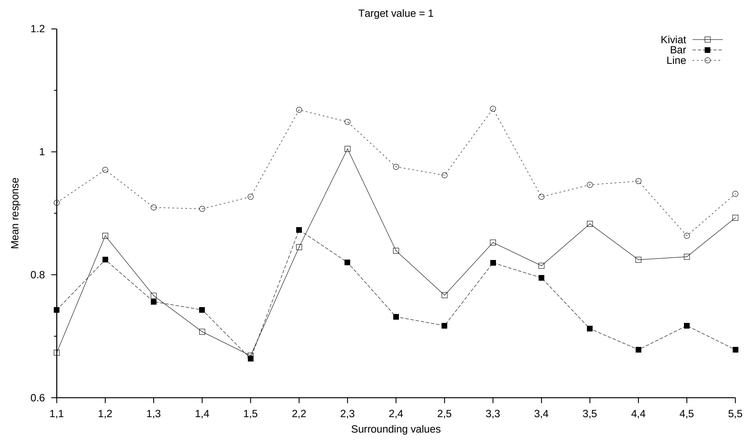

Figure 5: Mean responses to target 1.

The experiment was a mixed design with one between-subjects variable (diagram type) and two within-subjects variables (the value of the target domain and the values of the two domains adjacent to the target domain). Five target values were combined with 15 possible permutations of two adjacent values to create a total of 75 triplets. Participants saw all 75 triplets twice—a total of 150 trials—in random order.

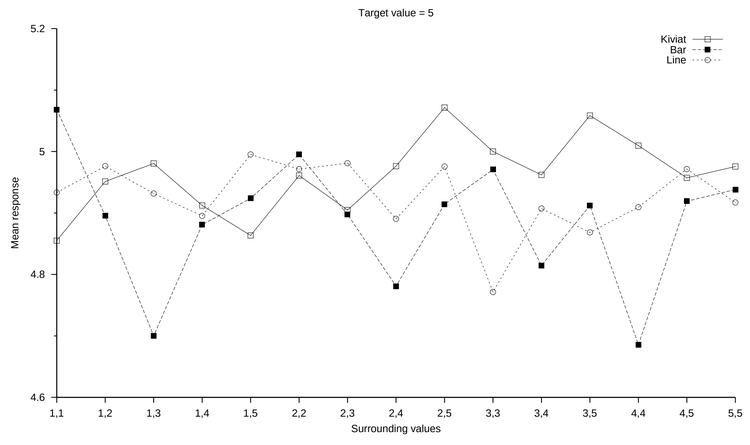

Figure 6: Mean response to target 5.

Sixty-three participants (twenty-one in each diagram condition) were asked to judge, as rapidly but also as accurately as possible, how much better or worse than average the performance of a particular authority was on a given domain, using the scale below the diagram.

Results

An ANOVA on the response data showed that the diagram used, the target value and the adjacent values all had a significant effect on participants' judgements of distance. These effects are illustrated in Figures 5 and 6 which plot mean responses for target values 1 and 5 respectively as a function of the adjacent values. The graphs show a wide variation in responses to individual target values both for individual diagrams and between the different diagram types.

Kiviat charts and the Müller-Lyer illusion

Figure 5 shows a particularly wide range of responses to target value 1 for the kiviat charts and the two kiviat diagrams shown in Figure 7 are good illustrations as they were given significantly different ($t(60.11) = 3.10$, $p < .001$) ratings at the extreme ends of the range. Both diagrams have a target value of 1 (education) with adjacent values of 1,1 (left) and 2,3 (right). Participants perceived the target value to be closer to the average when surrounded by the values 2,3 (rating = 1.0) than when surrounded by values 1,1 (rating = 0.67), demonstrating that the shape produced by the lines connecting the target value and the adjacent values has a distorting effect on viewers' perception of distance.

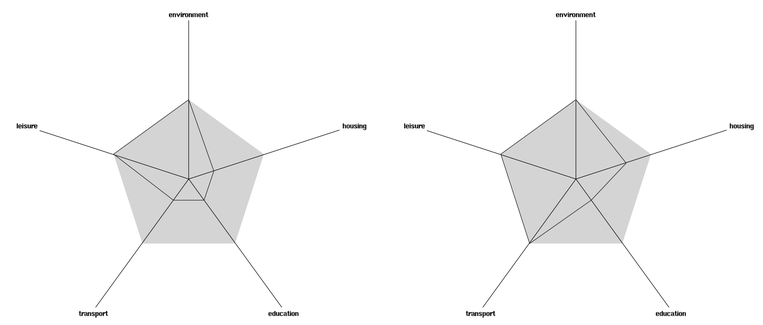

Figure 7: Kiviat charts with target value 1 (education) and adjacent values 1,1 (left) and 2,3 (right).

Bar charts and the Parallel Lines illusion

Figure 6 shows a wide range of responses to target value 5 for the bar charts. The two bar charts in Figure 8 were given significantly different ($t(76.02) = 3.88$, $p < .001$) ratings at extreme ends of the range. Both have a target value of 5 (education) with adjacent values of 1,1 (left), for which the mean rating was 5.07, and 4,4 (right), given a mean rating of 4.69. The target domain in the left-hand chart was perceived as being further away from the average line than that in right-hand chart. This can be explained in terms of the Parallel Lines illusion. The target domain in the left-hand chart is seen as being larger because it contrasts with two relatively small adjacent values whereas the target domain in the right-hand chart is perceived as being smaller because viewers perceive the lengths of the target and adjacent bars to be closer than they actually are (assimilation). This pattern of responses is not found in the line graph (Figure 6).

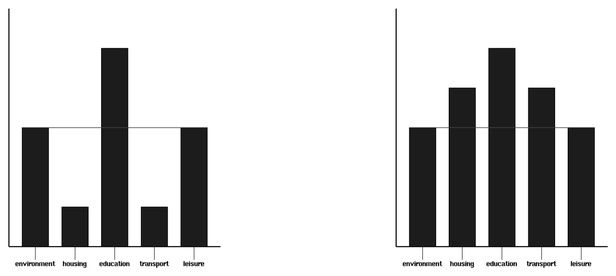

Figure 8: Bar charts with target value 1 (education) and adjacent values 1,1 (left) and 4,4 (right).

Conclusion

These results provide concrete evidence of distortions in perceptual judgements of distance in two graphical representations. Specifically, that simple comparative judgements between two points on a dimension can be significantly affected by the values of adjacent variables. The use of anchor points, typically tick marks on axes, facilitates the accurate reading of locations relative to a scale. Whether the incorporation of such anchor points into these diagrams reduces the distortions in distance judgements is to be tested in a future study.